CHARACTERIZATION OF TRUCK-MOUNTED ATOMIZATION EQUIPMENT TYPICALLY USED IN VECTOR CONTROL[1]

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ABSTRACT. The control of medically important arthropod vectors of human and animal disease is a high priority for both public health and military officials. Because droplet size of pesticide spray material is a critical factor affecting vector control applications, the droplet-size spectra produced by 11 sprayers and 3 spray formulations were evaluated. Droplet-size spectra were measured by a laser diffraction instrument, a hot-wire system, and rotating slides. There were considerable differences in the droplet-size spectra produced by the different sprayers tested. The volume median diameter ($D_{V0.5}$) for the water-based sprays ranged from 4.7 to 211 µm, depending on the sprayer, and the percent of spray volume contained in droplets less than 20 µm (%vol <20 µm) ranged between 0.5% and 98.9%. The $D_{V0.5}$ measurements for the oil-based sprays ranged from 9.4 to 125.3 µm and the %vol <20 µm ranged between 2.4% and 97.9%. The correlations between the $D_{V0.5}$ measured by the laser system ($D_{V0.5\text{-laser}}$) and the mass median diameter, Sauter diameter, and $D_{V0.5}$ measured by the AIMS probe were all significant. Generally, the slide $D_{V0.5}$s were numerically similar to the $D_{V0.5}$ from the laser system and the Sauter diameter from the Army Insecticide Measuring System probe. There was less consistent agreement between the % <32 µm values obtained from the slides and those from the other 2 samplers. The information presented can be used by applicators to select the sprayer that produces the droplet-size spectra needed for their particular application situation.

KEY WORDS Atomization, droplet size, sprayer, handheld sprayer, vector control

INTRODUCTION

The control of medically important arthropods is a high priority for both public health and military officials. One of the most common methods for controlling arthropod vectors, particularly mosquitoes, is the application of insecticides by either ground or aerial sprayers. When selecting spray equipment and insecticides, pesticide applicators utilize a lot of information to make the most effective application. Droplet size is one of the most significant factors that affect how well a vector control application works. Therefore, there is a need to obtain baseline droplet and spray cloud formation information on equipment that was or is currently in the Department of Defense (DoD) National Stock System so as to provide a method of comparison or evaluation for potentially new pest management equipment (i.e., electric or diesel-powered equipment).

When one is measuring droplet size from atomization equipment, the distance of the measuring system from the sprayer can be important. Droplets that are greater than 50 µm are generally not considered aerosol droplets (Matthews 1988); therefore, these droplets have a great propensity of settling out or depositing on the ground before reaching a slide located 3–10 m from the sprayer. This settling out of the large droplets biases the droplet spectrum measurements (toward smaller droplets) made by samplers placed too far away from the sprayer. Additional sampler bias can occur with very small droplets. Droplets that remain in the air, particularly those <20 µm, can have low collection efficiencies onto samplers (Rathburn 1970) and may be undersampled by slide analysis methods.

There have been numerous studies to determine the optimum or best droplet size to maximize vector control efforts (Himel 1969, Lofgren et al. 1973, Curtis and Beidler 1996, Crockett et al. 2002). Fewer studies have detailed specific droplet-size spectra for specific equipment (Younglove and McCool 1994, Brown et al. 1998a). Droplet size can be measured with water-sensitive cards (Hoffmann and Hewitt 2005), Teflon or magnesium oxide slides (Mount et al. 1970, Brown et al. 1998b, Meisch et al. 2005), or with laser-based systems (Picot et al. 1985, Young 1986). Numerous researchers have also evaluated specific products for their efficacy on controlling different species of mosquitoes (Inman at al. 1997, Ham et al. 1999, Crockett et al. 2002). It was beyond the scope of this study to consider a whole range of active spray ingredients.

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Fig. 1. Testing of truck-mounted atomizer equipment showing a vertical traverse of the spray plume with the droplet-sizing system.

Therefore, only 3 standard formulations were investigated: Aqua-Reslin® (permethrin and piperonyl butoxide, Bayer Environmental Science, Montvale, NJ) was used as the active formulation; water and oil were used as generics, typical within standard laser droplet-size evaluation protocols.

As a result of a Department of the Army policy, there is a need for equipment that does not run on gasoline-type fuel. Army Regulation AR 70-12 (1997) states that fuel support for ground forces in overseas theaters must use a single kerosene-type fuel, JP-8. In overseas theaters where the predominant fuel requirements support the Navy, PJ-5 may be substituted for JP-8. No new equipment designed to use gasoline-type fuels are to be acquired or developed, except for equipment not intended for deployment or employment outside of the continental United States. Therefore, manufacturers of spray equipment have developed diesel-driven sprayers, which were included in this study.

The objective of this study was to use a laser droplet analysis system to obtain baseline droplet and spray cloud formation information on available truck-mounted sprayers that are incorporated or could be included into DoD pest management programs. Spray droplets were also measured with the use of Teflon-coated slides and the Army Insecticide Measuring System (AIMS), allowing for a comparison of droplet-size data from 3 measurement regimes.

MATERIALS AND METHODS

A total of 34 replicated spray tests, comprised of 11 sprayers and 3 spray formulations, were completed for this study. The sprayers were selected from equipment that is commonly used for vector and flying insect control applications. The 7 formulations were divided into 2 groups,

water or oil based. The specific testing protocol, spray formulations, equipment tested, and physical property measurement procedures are discussed in the following sections.

Testing protocol

For each combination of sprayer and spray formulation, 3 independent replications were conducted. A replication comprised operating the sprayer for 30 sec at a distance of 90 cm (36 in.) from the laser beam of the droplet measuring system. During the 30 sec, the beam from the laser system was directed vertically downward to traverse and sample the entire spray plume (Fig. 1); sampling took between 15 and 20 sec. Simultaneously, Teflon-coated slides and the AIMS method were deployed to obtain comparative measurements of droplet size. Appropriate personal protective equipment, such as respirators, gloves, goggles, and Tyvex suits, were worn during all of the tests containing active ingredients.

Droplet-sizing system

A Sympatec Helos laser diffraction droplet-sizing system (Sympatec Inc., Clausthal, Germany) was utilized in this study. The Helos system uses a 623-nm He–Ne laser and was fitted with a R5 lens, which made the dynamic size range from 0.5 to 875 µm in 32 sizing bins. A specially constructed frame and forklift was used to traverse the system through the spray plume.

Volume mean diameter ($D_{V0.5}$) is the term used most commonly to describe spray droplet-size spectra. $D_{V0.5}$ is the droplet diameter (micrometers), where 50% of the spray volume or mass is contained in droplets smaller than this value. $D_{V0.1}$ and $D_{V0.9}$ values, which describe the proportion of the spray volume (10% and 90%, respectively) contained in droplets of the specified size or less, were also measured. The percent of spray volume contained in droplets less than 20 µm (%vol $<$20 µm) was calculated for all tests. This term (%vol $<$20 µm) allows the user of this equipment to determine the portion of the applied material that will most likely stay aloft after an application and potentially impinge on a flying insect. Persons using the equipment for barrier treatments, where deposition onto a target is the objective, may want to minimize this portion of the spray to keep the sprayed material from missing or drifting out of the target area.

Army Insecticide Measuring System

The AIMS probe uses hot-wire instrumentation to measure spray droplet size. The system was developed by KLD Industries (Huntington Station, NY). The KLD Industries model DCIII

Table 1. Spray formulations and dilution rates used in the atomization studies.[1]

Formulation	Description	Rate added to 1 liter of water[2]
Water + 90% NIS	90% NIS at 0.25% v/v	2.5 ml
Aqua-Reslin® 1:4	Water solution with Aqua-Reslin at 25% v/v	250 ml
BVA 13 ULV Oil	Oil solution with only BVA 13 ULV Oil	n/a

[1] NIS, nonionic surfactant.
[2] n/a, no water was added.

(AIMS) system was utilized, and measurements were taken according to the standard operating procedures provided with the unit. The probe was positioned directly in front of the machine nozzle, where the wind velocity was measured to be from 5.0 to 7.0 m/sec. Distance from the nozzles varied with pressure, make, and model. After each measurement the probe was cleaned with a solution of 50% acetone/50% xylene.

One thousand droplets were measured by the probe during each replication. The AIMS system software computed the mass median diameter (essentially equivalent to the volume median diameter, $D_{V0.5}$), Sauter mean diameter, and volume mean diameter, and also recorded the number of droplets greater than 30 μm of the 1,000 droplets measured. The number of droplets greater than 30 μm was converted to percent of droplets less than 30 μm (% <30 μm) for comparison to the % <32-μm (percent of droplets less than 32 μm) data measured by the laser system.

Rotating slides

Teflon-coated slides were collected with the use of a Hock Impinger (John. W. Hock Co., Gainesville, FL). The slides were 25-mm-wide Teflon-coated microscope slides and were rotated at 390–400 RPM. One of the unknowns with a rotating slide is the collection efficiency associated with different droplet sizes. The Hock Impinger was positioned approximately 3 m away from but directly in front of the outlet of the sprayer. After being exposed to the spray cloud for 5–10 sec, the slides were removed from the holders and placed in sealed slide racks to prevent any additional exposure. One hundred randomly selected droplets were measured under a calibrated microscope. The volume median diameter ($D_{V0.5}$) for each slide was computed by inputting the collected droplet data into the Droplet Analysis Program available from Adapco Inc. (Sanford, FL; www.adapcoinc.com).

Spray formulations

Three different spray formulations (Table 1) were evaluated. The formulations selected are products that are commonly used in vector control scenarios. One formulation contained the active ingredient Aqua-Reslin, whereas the other 2 formulations (water + 90% nonionic surfactant [NIS] and BVA Oil) were used as mimics of real-world solutions to limit the use of mixtures containing active ingredients. These mimics or generic sprays allow users to test equipment without having to use personal protective equipment such as respirators and chemical suits, while ensuring that the droplet-size spectrum is similar to that obtained with active ingredient (Hoffmann et al. 2007).

Equipment

Eleven truck-mounted sprayers were evaluated in this study. All of the sprayers tested are considered ultra-low volume (ULV) sprayers, except the Buffalo Turbine sprayer, which is considered a low-volume (LV) sprayer. These sprayers are referred to as truck mounted, because most of the sprayers are too heavy to be carried by a person and must be mounted in the back of a moving vehicle during spray operations. Three of the sprayers were powered by diesel engines, which meet the requirements of Army Policy AR 70-12.

Beecomist Systems Pro-Mist ULV Fogger 15 MP, AGULVE with aluminum frame (Beecomist Systems, Inc., Telford, PA; Pro-Mist is a Clarke product now [Clarke Mosquito Control, Roselle, IL]): The Pro-Mist is an all-electric, lightweight ULV space sprayer that produces a pesticide droplet spectrum by the use of a high-speed, porous-sleeve rotary nozzle with the resulting aerosol being dispersed by an axial fan. The fogger has a net weight of 137 lb (62.3 kg), and a maximum flow rate of 6.0 oz/min (177.4 ml).

Clarke Grizzly® (Clarke Mosquito Control): The Grizzly is powered by an 18-hp (694 cc) Briggs & Stratton gasoline engine that drives a rotary positive displacement blower. The blower provides the air blast that creates a pesticide droplet spectrum at the laminar air-flow nozzle. The unit weighs 475 lb (216 kg) and has a maximum flow rate of 18.0 oz/min (532.3 ml).

B&G Phoenix Fogger 680 (B&G Chemicals & Equipment Co, Inc., Dallas, TX): The Phoenix Fogger 680 is powered by a 6.8-hp Lombardini diesel engine that drives a positive displacement lobe blower. The blower provides the air blast that shears the pesticide into droplets at the

nozzle. The fogger weighs 310 lb and has a flow-rate capacity of 35.0 oz/min (1,035 ml).

London Fog XKD (London Fog, Long Lake, MN): The XKD is a heavy-duty cold fogger that is powered by a 7-hp Hatz diesel engine. The XKD produces a pesticide droplet spectrum by means of a positive-displacement* 4-cylinder compressor and a single nozzle. The unit weighs 271 lb (123.2 kg) and has a flow-rate capacity of 18.0 oz/min (532.3 ml).

London Fog 18–20 (London Fog): The 18–20 is a high-output ULV aerosol generator that is powered by an 18-hp gasoline engine. The 18–20 produces a pesticide droplet spectrum by means of a rotary positive displacement blower and a nylon nozzle. The unit weighs 445 lb (202 kg) and has a flow-rate capacity of 20.0 oz/min (591.4 ml).

London Fog, Medium Area Generator (M.A.G.), Chemical Aerosol Generator (London Fog): The M.A.G. is an ULV aerosol generator that is powered by a 3.5-hp Briggs & Stratton gasoline engine. It produces a pesticide droplet spectrum by means of a single-stage 2-cylinder compressor and a single nozzle. The unit weighs 110 lb (50 kg) and has a flow-rate capacity of 10.0 oz/min (295 ml).

Whitmire Micro-Gen Chemical Dispersal Unit, Model G-4 (Whitmire Micro-Gen Research Laboratories, Inc., St. Louis, MO): The Model G-4 is a ULV chemical dispersal unit powered by a 5-hp Briggs & Stratton gasoline engine. The pesticide droplet spectrum is created by a nozzle–compressor combination that produces a blast of air, which causes a shearing of the pesticide as it passes through the spray nozzle. The unit has a net weight of 78.5 lb (35.7 kg), and a maximum flow rate of ca 6.0 oz/min (177.4 ml).

Advanced Specialized Technologies Terminator (Advanced Special Technologies, Winnebago, MN): The Terminator's 4.7-hp (219 cc) Yanamar diesel engine powers a direct-drive air compressor. The compressed air atomizes the spray at the outlet of the stainless-steel nozzle where the air and liquid meet. The unit weighs 125 lb, and has a 3–6 oz/min (88.7–177.4 ml) flow-rate capacity. The Terminator can be used as a portable compressor when not being used as a sprayer.

LECO ULV Fog Generator Model MD, Series D (Lowndes Engineering Co., Inc., Valdosta, GA; Clarke now owns the patents for LECOs): The LECO Model MD, Series D, is a ULV fog generator powered by an 11-hp Briggs & Stratton gasoline engine. The pesticide droplet spectrum is produced by a shearing action at the nozzle as the result of the air blast created by a rotary positive-displacement blower. The unit weighs 360 lb (150 kg) and has a maximum flow rate of 14 oz/min.

Buffalo Turbine Model CSM2 Turbine Mist Sprayer (Buffalo Turbine LLC, Springville, NY):

Table 2. Physical properties of spray solutions tested.[1]

Spray solution	Dynamic surface tension (mN/m @ 20 msec)	Viscosity (cP @ 20°C)
Water	73	1.0
Water + 90% NIS	49.8	1.1
Aqua-Reslin® 1:4	40.5	1.3
BVA 13 ULV Oil	33.9	17.1

[1] NIS, nonionic surfactant.

The Model CSM2 is a mist sprayer powered by a 23-hp Kohler gasoline engine. The spray mist is created by a blower capable of an air blast of up to 10,000 cfm and a Hypro twin piston pump capable of a 10-gal/min output. The unit weighs 650 lb (295.5 kg) without the trailer.

Physical property measurements

Surface tension and viscosity have a significant effect on spray droplet spectra (Bellinger et al. 1996). Dynamic surface tension was measured with a SensaDyne Surface Tensiometer 6000 (Chem-Dyne Research Corp., Mesa, AZ) with the use of the maximum bubble pressure method. The gas flow-rate settings were varied until surface age values were found less than and greater than 0.02 sec. Then, a table of percent flow-rate settings was built in 5% increments to include the previous settings. This table was calibrated with the use of 200-proof ethanol and pure water. The probes were lowered into the sample, and the dynamic surface tension, bubble rate, bubble age, and temperature were measured at each setting in the table. The dynamic surface tension at 20 msec was linearly interpolated from the results. The tests were replicated 3 times.

Viscosity was measured with a Brookfield Synchro-Lectric Viscometer (Model LVT, Brookfield Engineering, Middleboro, MA) with the use of a UL adapter with 0.1–100 centipoise range. The spindle was inserted into the sample, and the motor was started and run until the dial reading stabilized and the reading was recorded.

Statistical analyses

The Proc CORR in SAS was used to calculate correlation coefficients between variables based on the Pearson product-moment correlation coefficients. Pearson coefficient values close to 1 indicate a high degree of linear correlation between variables tested. Significant correlations were declared at the $P < 0.05$ level. To determine statistical significance between data sets, the Proc GLM procedure was used with $\alpha = 0.05$.

Table 3. Spray droplet measurements from the laser diffraction system for water-based sprays.

Sprayer	Spray solution[1]	Flow rate (oz/min)	$D_{v0.1}$ (μm ± SD)	$D_{v0.5}$ (μm ± SD)	$D_{v0.9}$ (μm ± SD)	%vol <20 μm
Pro-Mist ULV Fogger 15 MP	Water + 90% NIS	4	14.9 ± 0.6	34.7 ± 1.4	40.9 ± 6.2	31.9
		18	14.8 ± 0.3	32.2 ± 1.2	57.2 ± 0.7	19.6
Clarke Grizzly®	Water + 90% NIS	4	8.8 ± 0.3	25.9 ± 0.6	46.4 ± 1.0	33.5
B&G Phoenix Fogger 680	Water + 90% NIS	4	6.9 ± 0.5	25.1 ± 0.3	46.8 ± 1.3	36.0
		9	7.2 ± 1.0	27.8 ± 0.2	51.9 ± 0.4	31.1
London Fog XKD	Water + 90% NIS	4	1.3 ± 0.0	4.7 ± 0.2	11.9 ± 0.4	98.9
		17	7.6 ± 0.1	29.7 ± 1.1	112.5 ± 6.7	35.9
London Fog 18–20	Water + 90% NIS	4	11.1 ± 0.2	19.2 ± 0.1	29.8 ± 0.4	54.1
		18	8.1 ± 0.1	15.3 ± 0.1	25.7 ± 0.0	72.7
London Fog MAG	Water + 90% NIS	4	7.6 ± 0.1	25.6 ± 0.7	60.6 ± 1.8	37.6
LECO ULV Fog Generator Model MD	Water + 90% NIS	4	6.0 ± 0.0	12.6 ± 1.3	29.2 ± 4.3	79.7
Whitmire Micro-Gen Model G4	Water + 90% NIS	4	8.6 ± 0.5	23.3 ± 0.3	42.2 ± 0.7	39.5
AST Terminator	Water + 90% NIS	4	7.6 ± 1.2	20.4 ± 2.7	48.5 ± 6.0	40.6
Buffalo Turbine Model CSM2	Water + 90% NIS	128	93.1 ± 15.3	211.0 ± 31.1	315.1 ± 37.1	0.5
		120	73.0 ± 2.7	174.4 ± 26.0	269.8 ± 54.1	0.9
Clark Pro-Mist ULV Fogger	Aqua-Reslin® (1:4)	4	15.6 ± 8.0	26.5 ± 0.4	36.1 ± 0.4	13.3
B&G Phoenix Fogger 680	Aqua-Reslin (1:4)	4	8 ± 0.1	20.7 ± 0.7	38.4 ± 1.7	47.8
London Fog XKD	Aqua-Reslin (1:4)	4	2.1 ± 0.1	8.5 ± 0.6	19.9 ± 1.5	90.1
London Fog 18–20	Aqua-Reslin (1:4)	4	8.2 ± 0.0	15.3 ± 0.0	24.8 ± 0.0	74.1
AST Terminator	Aqua-Reslin (1:4)	4	5.5 ± 0.1	19.0 ± 0.7	41.9 ± 1.5	35.4

[1] NIS, nonionic surfactant.

Table 4.   Spray droplet spectra data from the laser diffraction system for sprayers applying BVA 13 ULV Oil.

Sprayer	Flow rate (oz/min)	$D_{V0.1}$ (μm ± SD)	$D_{V0.5}$ (μm ± SD)	$D_{V0.9}$ (μm ± SD)	%vol <20 μm
Pro-Mist ULV Fogger	4	2.20 ± 0.1	20.4 ± 0.3	34.7 ± 0.2	48.8
15 MP	18	4.1 ± 0.1	25.0 ± 0.2	42.2 ± 0.4	35.0
	1.5	2.7 ± 0.1	22.3 ± 0.2	34.6 ± 0.1	40.0
Clarke Grizzly®	4	3.5 ± 0.2	17.5 ± 0.5	38.6 ± 1.7	56.4
B&G Phoenix Fogger					
680	4	3.4 ± 0.2	20.1 ± 1.1	44.0 ± 3.2	49.8
London Fog XKD	4	2.3 ± 0.1	9.4 ± 0.1	20.7 ± 0.5	88.6
@100 psi	18	5.1 ± 0.1	30.5 ± 0.8	76.7 ± 3.7	33.1
@120 psi	18	4.7 ± 0.4	26.1 ± 1.4	99.6 ± 5.0	40.1
	1	1.3 ± 0.1	4.8 ± 0.6	12.5 ± 2.9	97.9
London Fog 18–20	4	5.3 ± 0.8	13.8 ± 0.8	25.0 ± 1.6	76.8
	18	6.1 ± 0.1	14.6 ± 0.2	26.6 ± 0.6	73.1
	0.8	3.4 ± 0.4	19.9 ± 1.2	40.5 ± 2.3	50.3
London Fog MAG	4	3.5 ± 0.1	14.7 ± 0.7	32.3 ± 1.8	66.5
AST Terminator					
No. 24 Orifice	4	3.6 ± 0.3	17.2 ± 0.2	38.8 ± 0.1	54.6
No. 35 Orifice	4	4.6 ± 0.3	21.7 ± 0.8	46.4 ± 1.9	45.2
No. 41 Orifice	4	4.2 ± 0.3	21.6 ± 1.0	46.7 ± 2.3	45.6
Whitmire Micro-Gen					
Model G4	4	3.5 ± 0.2	17.5 ± 0.5	36.5 ± 0.6	57.2
Buffalo Turbine	128	43.9 ± 3.0	125.3 ± 12.0	212.4 ± 28.4	2.5
Model CSM2	103	43.2 ± 2.1	122.5 ± 7.3	204.5 ± 15.6	2.4

RESULTS

Physical properties

The physical properties of a spray solution are important factors that affect atomization of a spray (Butler et al. 2001). Given the large number of tests conducted, it was desirable to use solutions that mimicked active-ingredient sprays but limited the exposure of the testing personnel and the environment to the active ingredients. The physical properties of all solutions tested are shown in Table 2, with water given as a reference. The addition of a 90% NIS (Wilbur-Ellis, San Antonio, TX) at a 0.1% rate to water was used to mimic the physical properties of the Aqua-Reslin solution.

Water-based sprays atomization results

A primary objective of this work was to provide system users with droplet-size spectra data, not to rank system performance. As such, statistical ranking of the sprayers was not undertaken for these data. Droplet-sizing data from the Sympatec Helos laser systems for the water-based sprays is given in Table 3. The $D_{V0.5}$ measurements for the water-based sprays ranged from 4.7 to 211 μm, depending on the sprayer. The %vol <20 μm ranged between 0.5% and 98.9%. The standard deviations (SDs) for almost all tests were very low, which is indicative of the repeatability of the laser measurements.

The water + 90% NIS solution did not prove to mimic the Aqua-Reslin formulation as closely as anticipated. For the Pro-Mist sprayer at a flow rate of 4 oz/min, the $D_{V0.5}$ was 34.7 μm with the water + 90% NIS solution and 26.5 μm for the Aqua-Reslin solution. For 3 of the 4 sprayers tested, the water + 90% NIS solution created larger droplets than those generated with the Aqua-Reslin solution. The difference in $D_{V0.5}$ values between the 2 spray solutions was significantly different ($P < 0.001$) for all 4 sprayers where both solutions were tested. This difference was likely caused by the higher dynamic surface tension for the water + 90% NIS solution (49.8 mN/m) than that of the Aqua-Reslin solution (40.5 mN/m).

Oil-based sprays atomization results

Oil-based sprays make up the majority of adult mosquito control products used in the USA. Droplet-sizing data from the laser measurement system is given in Table 4. The $D_{V0.5}$ measurements for the oil-based sprays ranged from 9.4 to 125.3 μm, depending on the sprayer. The %vol <20 μm ranged between 2.4% and 97.9%. The Buffalo Turbine is primarily used in barrier treatments, where large droplet size is important, so that the spray material will deposit on the foliage. These results compliment the previous work, which showed that BVA Oil is a good mimic of the oil-based insecticide Anvil 10+10® (Hoffmann et al. 2007).

Table 5. Spray droplet spectra data as measured by the AIMS Probe, Sympatec laser system, and rotating slides.

	Flow rate (oz/min)	AIMS probe measurements				Sympatec		Rotating slides	
		MMD	Sauter	$D_{vo.5}$ (µm SD)	% <30 µm	$D_{vo.5}$ (µm ± SD)	% <32 µm	$D_{vo.5}$ (µm ± SD)	% <32 µm
Aqua-Reslin® Sprayer									
Clarke Pro-Mist ULV Fogger	4	31.2 ± 1.2	23.5 ± 1.0	10.0-1.2	91.2 ± 1.9	20.6 ± 0.7	77.0 ± 2.5		
B&G Phoenix Fogger	4	30.5 ± 1.73	19.2 ± 0.4	7.7-0.1	96.5 ± 0.5	20.6 ± 0.7	76.8 ± 2.63		
London Fog XKD	4	19.5 ± 3.7	10.4 ± 1.6	4.7 ± 0.3	99.4 ± 0.7	15.3 ± 0.1	97.3 ± 0.6	11.8	100
London Fog 1820	4	21.5 ± 2.6	13.3 ± 1.1	6.1 ± 0.3	99.2 ± 0.4	15.3 ± 0.1	97.3 ± 0.1	12.3	100
BVA 13 ULV Oil Sprayer									
Clarke Pro-Mist ULV Fogger	4	23.8 ± 0.6	15.0 ± 0.5	7.1 ± 0.3	98.5 ± 0.2	20.4 ± 0.3	81.5 ± 0.9	23.8	85.9
B&G Phoenix Fogger	4	29.0 ± 2.6	16.5 ± 1.6	6.5 ± 0.5	97.0 ± 1.2	20.0 ± 0.9	72.5 ± 2.8	20.2	93.4
London Fog XKD (@100 psi)	4	22.8 ± 0.6	18.7 ± 0.6	12.8 ± 0.8	97.1 ± 0.1	9.4 ± 0.1	98.3 ± 0.9	19.4	79.3
	18	39.8 ± 0.6	38.6 ± 2.1	28.9 ± 2.5	54.0 ± 7.0	30.5 ± 0.6	49.3 ± 0.8		
	1	15.8 ± 3.1	12.9 ± 2.6	9.3 ± 2.0	99.2 ± 0.6	4.8 ± 0.6	98.7 ± 0.86		
London Fog 1820	4	19.8 ± 1.5	11.6 ± 0.5	5.5 ± 0.1	99.4 ± 0.4	13.8 ± 0.8	97.2 ± 2.5		
	18	22.0 ± 1.7	14.2 ± 1.0	6.8 ± 0.4	98.5 ± 0.3	14.6 ± 0.2	95.2 ± 0.6		
	0.8	30.0 ± 3.1	14.1 ± 1.4	5.3 ± 0.4	98.4 ± 0.7	19.9 ± 1.2	72.6 ± 3.0		
Clarke Grizzly®	4	28.2 ± 2.1	15.7 ± 1.4	6.5 ± 0.4	98.4 ± 0.5	17.5 ± 0.5	78.3 ± 2.0		
London Fog MAG	4	33.8 ± 0.6	29.2 ± 1.8	20.3 ± 2.9	78.4 ± 5.8	14.7 ± 0.7	87.6 ± 2.1		
Whitmire Micro-Gen Model G4	4	33.5 ± 1.0	29.2 ± 2.1	20.5 ± 2.6	73.8 ± 8.3	17.5 ± 0.5	81.1 ± 1.2		

[1] MMD, mass median diameter.

Comparison of droplet measurement systems

The spray droplet spectra produced by different sprayers was simultaneously measured with the AIMS probe, Sympatec, and rotating slide for 15 of the tests performed (Table 5). The rotating slides were only deployed during 1 replication; therefore, there are no SDs. The AIMS and laser measurements were taken for each of the 3–4 replications for each sprayer evaluated.

The correlations between the $D_{V0.5}$ measured by the laser system ($D_{V0.5\text{-laser}}$) and the mass median diameter (MMD), Sauter diameter, and volume mean diameter measured by the AIMS probe were all significant ($P < 0.05$). There was a stronger correlation between $D_{V0.5\text{-laser}}$ and the MMD (Pearson coefficient $= 0.78$, $n = 49$, $P < 0.0001$) than between $D_{V0.5\text{-laser}}$ and Sauter diameter (Pearson coefficient $= 0.56$, $n = 49$, $P < 0.0001$) or between $D_{V0.5\text{-laser}}$ and volume mean diameter (Pearson coefficient $= 0.39$, $n = 49$, $P < 0.006$). There was also a significant correlation between the % <32 μm and % <30 μm (Pearson coefficient $= 0.61$, $n = 49$, $P < 0.0001$).

The data for the rotating slides are limited (Table 5). Generally, the slide $D_{V0.5}$s were numerically similar to the $D_{V0.5}$ from the laser system and the Sauter diameter from the AIMS Probe and similar to the results from Brown et al. (1993). There was less consistent agreement between the % <32-μm values obtained from the slides and those from the other 2 samplers. Because the droplets captured on the slides have to be counted manually, this slide methodology takes considerably longer than the other 2 measurement systems tested.

DISCUSSION

The objectives of this work were to present not only information on droplet size generated by different sprayers, but to compare methodologies by which other similar systems can be evaluated and give applicators sprayer-system performance data. The conclusions from the work presented were:

● A total of 34 replicated spray tests, comprised of 11 sprayers and 3 spray formulations, were completed for this study. The information presented can be used by applicators to select the sprayer that produces the droplet-size spectra needed for their particular application situation.

● There were considerable differences in the droplet-size spectra produced by the different sprayers tested. The $D_{V0.5}$ measurements for the water-based sprays ranged from 4.7 to 211 μm, depending on the sprayer; the %vol <20 μm ranged between 0.5% and 98.9%. The $D_{V0.5}$ measurements for the oil-based sprays

ranged from 9.4 to 125.3 μm, depending on the sprayer, and the %vol <20 μm ranged between 2.4% and 97.9%.

● The correlations between the $D_{V0.5}$ measured by the laser system ($D_{V0.5\text{-laser}}$) and the MMD, Sauter diameter, and volume mean diameter measured by the AIMS probe were all significant.

● Generally, the slide $D_{V0.5}$s were numerically similar to the $D_{V0.5}$ from the laser system and the Sauter diameter from the AIMS Probe. There was less consistent agreement between the % <32 μm values obtained from the slides and those from the other 2 samplers.

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